How to Calculate Sample Size

A student-friendly lecture on precision, power, confidence, margins of error, and practical sample size decisions in research.

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$$n = Z^2 p(1-p) / e^2$$

Confidence • Precision • Power

95% confidence

±5% margin

80% power

Lecture Overview

- Why sample size matters in academic research
- Key terms: population, confidence level, margin of error, power, effect size, variance
- Formulas for proportions, means, finite populations, and hypothesis testing
- Step-by-step calculation process with worked examples
- Common mistakes, ethics, best practices, classroom activities, and knowledge check

Good sample size planning balances accuracy, ethics, cost, and feasibility.

Learning Objectives

1. Define sample size and related statistical terms accurately.

2. Explain how confidence level, margin of error, variability, and power affect sample size.

3. Select an appropriate sample size approach for common research designs.

4. Calculate sample size for a proportion and adjust it for finite populations and nonresponse.

5. Recognize common errors in sample size justification.

6. Document sample size decisions transparently in a methodology section.

Introduction: What Is Sample Size?

Sample size is the number of units, participants, cases, records, or observations included in a study.

- It determines how much evidence the study can collect.
- Too small a sample can produce unstable or underpowered results.
- Too large a sample can waste time, money, and participant effort.
- The “right” sample size depends on the research question and design.

The goal is not “as many as possible” — it is enough evidence for the study purpose.

Key Definitions

Term	Student-friendly meaning
Population	The full group the researcher wants to understand.
Sample	The selected subset of the population studied directly.
Sampling unit	One member or element selected for the sample.
Parameter	A true value in the population, often unknown.
Statistic	A value calculated from the sample.
Sampling error	Difference between a sample estimate and the true population value.

Background and Academic Context

- Sample size planning developed from sampling theory, survey methodology, experimental design, and statistical power analysis.
- In descriptive studies, the focus is precision: “How close is the estimate to the population value?”
- In hypothesis-testing studies, the focus is power: “Can the study detect a meaningful effect?”
- Modern research reporting expects transparent justification, not only a final number.

Precision

Used for estimating percentages, means, rates, and averages.

Power

Used when testing differences, associations, effects, and interventions.

Why Sample Size Matters

Validity
Increases confidence that sample results reasonably represent the target population.

Precision
Reduces uncertainty around estimates, such as percentages and means.

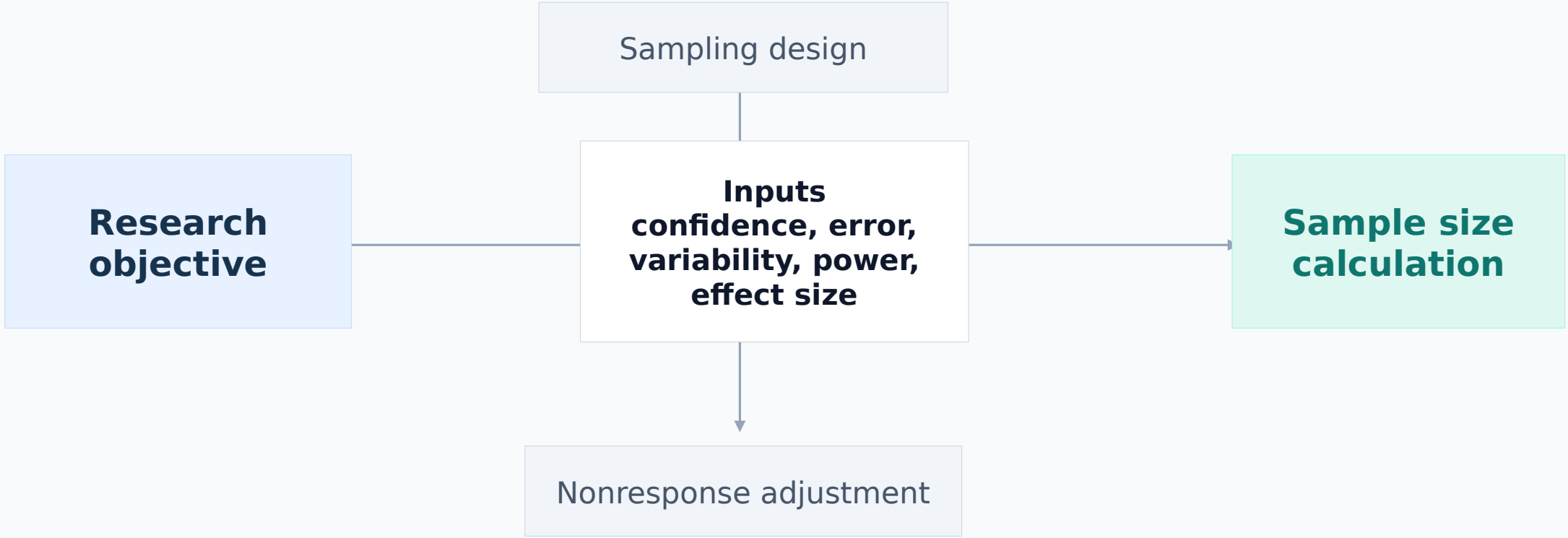
Statistical power
Improves the chance of detecting real effects when they exist.

Ethics
Avoids exposing participants to unnecessary burden or underpowered research.

Resources
Supports realistic budgeting, scheduling, staffing, and data collection planning.

Publication quality
Strengthens the methodology section and peer-review credibility.

Main Concept Map



Report the final number and assumptions clearly in the methodology section.

Factors That Influence Sample Size

Factor	Effect on sample size	Example
Higher confidence level	Increases sample size	99% needs more cases than 95%.
Smaller margin of error	Increases sample size	±3% needs more cases than ±5%.
Greater variability	Increases sample size	Unknown p is often estimated as 0.50.
Larger expected effect	Decreases sample size	Large treatment effects are easier to detect.
Lower expected response rate	Requires oversampling	Invite more people to reach the target.
Complex sampling design	May increase sample size	Cluster sampling may need a design effect.

Types of Sample Size Questions

Descriptive proportion
How many people are needed to estimate a percentage?

Descriptive mean
How many observations are needed to estimate an average?

Finite population
How should sample size change when the population is small?

Power analysis
How many participants are needed to detect a meaningful effect?

Complex survey
How should clustering, stratification, and weights be considered?

Qualitative study
How many participants are enough to reach depth or saturation?

Calculating Sample Size for a Proportion

$$n_0 = Z^2 \times p(1 - p) / e^2$$

Use when estimating a percentage or proportion in a large population.

- n_0 = initial sample size before adjustments
- Z = Z-score for the selected confidence level
- p = expected proportion; use 0.50 when unknown for a conservative estimate
- e = margin of error expressed as a decimal, such as 0.05

Confidence level	Common Z value
90%	1.645
95%	1.960
99%	2.576

Best for surveys measuring percentages: support, satisfaction, awareness, prevalence, adoption, or agreement.

Worked Example: Survey Proportion

Researcher wants to estimate the percentage of students satisfied with online learning.

95% confidence → Z = 1.96

Unknown p → 0.50

Margin of error → 0.05

Large population

$$n_0 = (1.96^2 \times 0.50 \times 0.50) / 0.05^2$$
$$= 384.16 \rightarrow \text{round up to } 385$$

Interpretation
The researcher should collect at least 385 completed responses before nonresponse or design adjustments.

Finite Population Correction

$$n = n_0 / [1 + (n_0 - 1) / N]$$

Use when the total population is known and relatively small.

- N = total population size
- n_0 = initial sample size calculated for a large population
- n = adjusted sample size for the finite population
- The correction reduces the sample size when the sample is a large share of the population.

Example: N = 2,000 and n_0 = 384.16
$n = 384.16 / [1 + (383.16 / 2000)]$
$n = 322.34 \rightarrow 323$

Use this adjustment only after defining the population clearly.

Calculating Sample Size for a Mean

$$n_0 = (Z \times \sigma / e)^2$$

Use when estimating a population mean or average.

- σ = estimated population standard deviation
- e = acceptable error in the same units as the mean
- Use pilot data, previous studies, or a reasonable planning estimate for σ.
- A larger standard deviation means a larger sample is needed.

Example

Estimate average study hours with ±1 hour error, 95% confidence, and estimated σ = 8 hours.

$n_0 = (1.96 \times 8 / 1)^2 = 245.86 \rightarrow 246$

Sample Size for Hypothesis Testing

- When a study compares groups or tests an association, sample size should be based on statistical power.
- Power is the probability of detecting a real effect when that effect exists.
- Common inputs include significance level, desired power, expected effect size, variability, and study design.
- Power analysis is especially important in experiments, clinical studies, and intervention research.

Typical planning inputs

α
Significance level

Power
Often 80% or 90%

Effect size
Minimum meaningful difference

σ / variability
Expected spread in data

Design
Groups, repeated measures, clusters

Design Effect and Complex Samples

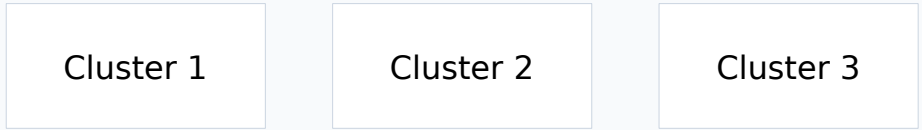
Simple formulas assume simple random sampling. Clustered or multistage designs often need adjustment.

Adjusted n = n × DEFF

DEFF = design effect. Values greater than 1 increase the required sample size.

Visual idea
Simple random sample: independent dots
Cluster sample: dots grouped inside clusters

- Cluster sampling may select naturally grouped units such as schools, villages, classes, or hospitals.
- Responses within the same cluster may be more similar than responses from different clusters.
- Design effect protects against loss of statistical efficiency in complex samples.
- Use expert guidance, survey design literature, or previous similar studies when choosing DEFF.



Adjusting for Nonresponse

Final invitations = required completed sample / expected response rate

Use response rate as a decimal, such as 0.80 for 80%.

Example: A study needs 323 completed responses and expects an 80% response rate. Invitations = 323 / 0.80 = 403.75 → invite at least 404 participants.

- Base the expected response rate on previous studies, pilot testing, or realistic field experience.
- Oversampling does not fix biased nonresponse; it only helps reach the numerical target.
- Plan follow-ups, reminders, incentives, and accessible data collection procedures.

Procedure

Step-by-Step Sample Size Process

- Each decision should be linked to the research question and study design.
- Document assumptions so readers can understand and evaluate the sample size justification.
- When unsure, consult a statistician or use validated software/calculators carefully.

Integrated Calculation Example

Planning input	Value
Population size (N)	5,000 employees
Confidence level	95% → Z = 1.96
Expected proportion	p = 0.50
Margin of error	e = 0.05
Expected response rate	70%

1) Initial sample
n_0 = 384.16 → 385

2) Finite population correction
n = 384.16 / [1 + 383.16/5000] = 356.8 → 357

3) Nonresponse adjustment
357 / 0.70 = 510

Interpretation: Invite about 510 employees to obtain approximately 357 completed responses.

Practical Examples Across Disciplines

Discipline	Example sample size question	Likely approach
Social sciences	What percentage of citizens trust local government?	Proportion + margin of error
Business	What is the average customer satisfaction score?	Mean + standard deviation
Education	Do two teaching methods produce different test scores?	Power analysis for group comparison
Health sciences	What is the prevalence of a condition in a clinic population?	Proportion + finite population if needed
Psychology	Is there an association between stress and sleep quality?	Power analysis for correlation/regression
Information technology	What percentage of users adopt a new app feature?	Proportion or A/B test power analysis

Application Example

Detailed Research Scenario

Element	Scenario detail
Research topic	Student satisfaction with online learning in a university
Research problem	The university needs reliable evidence to improve online course delivery.
Research question	What proportion of enrolled students are satisfied with online learning?
Population	All 12,000 enrolled students at the university
Data collection	Online questionnaire using stratified sampling by faculty
Sample size plan	Use proportion formula with 95% confidence, ±5% error, p = 0.50, finite population correction, and response-rate adjustment.
Analysis	Descriptive statistics and confidence interval for satisfaction percentage
Interpretation	If the sample is representative, results estimate university-level satisfaction within the planned precision.

Strengths

Advantages of Proper Sample Size Calculation

Improves credibility
Provides a transparent reason for the number of participants.

Controls uncertainty
Connects estimates to confidence levels and margins of error.

Supports feasibility
Helps plan budget, time, staff, and data collection workload.

Strengthens analysis
Improves chances that statistical tests are meaningful.

Protects participants
Avoids unnecessary burden and underpowered research.

Improves reporting
Makes methodology sections clearer for supervisors, reviewers, and readers.

Limitations and Challenges

- Formulas depend on assumptions that may be uncertain before data collection.
- A large sample cannot correct a biased sampling frame or poor measurement tool.
- Nonresponse may create bias even when the target number is reached.
- Complex designs may require specialist statistical input.
- Ethical, budgetary, and field constraints may limit what is achievable.
- Qualitative sample size depends on depth, diversity, and saturation rather than a single universal formula.

**Sample size improves quantity of evidence —
but it does not automatically improve quality of evidence.**

Common Mistakes to Avoid

- Choosing a sample size only because previous studies used it.
- Using the wrong formula for the research objective.
- Forgetting to convert percentages to decimals in formulas.
- Rounding sample size down instead of up.
- Ignoring expected nonresponse or incomplete questionnaires.
- Confusing number invited with completed sample size.
- Claiming representativeness without a suitable sampling method.
- Reporting a final number without assumptions or justification.

Best Practices for Researchers

Best practice	Why it matters
Start with the research question	The objective determines the formula or power method.
Define the population precisely	Population size and sampling frame affect calculation and interpretation.
Use conservative assumptions when needed	Unknown variability may require cautious planning.
Adjust for nonresponse	Completed responses are usually fewer than invitations.
Document all assumptions	Readers need to understand how the number was produced.
Use software carefully	Calculator outputs are only as good as the input assumptions.
Seek statistical advice for complex designs	Clustered, longitudinal, multilevel, and clinical designs may need advanced methods.

Comparison Table: Common Approaches

Approach	Best used for	Key inputs	Main caution
Proportion formula	Estimating a percentage	Z, p, margin of error	Not for testing group differences
Mean formula	Estimating an average	Z, standard deviation, error	Needs a realistic SD estimate
Finite population correction	Known small population	N and initial n_0	Use only after initial n_0
Power analysis	Testing effects or comparisons	α, power, effect size, variance	Effect size must be meaningful
Qualitative saturation	Interviews, focus groups, case studies	Study aim, diversity, saturation	No universal fixed number

Ethical Considerations

Avoid underpowered studies
A study too small to answer its question can waste participant time and resources.

Avoid unnecessary recruitment
Oversized studies may burden more participants than needed.

Be transparent
Report assumptions, formulas, software, and adjustments honestly.

Protect privacy
Recruitment lists, survey records, and participant data must be handled confidentially.

Reduce bias
Do not use sample size as a substitute for fair sampling and inclusive recruitment.

Respect consent
Sample size targets must not pressure people into participation.

Classroom Activity: Calculate and Justify

Activity objective
Students practice selecting inputs, calculating sample size, and writing a short justification.

Instructions
In pairs, calculate sample size for a survey estimating the proportion of students who use AI tools for study. Use 95% confidence, ±5% margin of error, p = 0.50, population N = 8,000, and 75% expected response rate.

Expected outcome
Students should report the required completed sample, the number of invitations needed, and a two-sentence methodology justification.

Instructor tip: Ask groups to compare assumptions and explain how the final number changes when margin of error becomes ±3%.

Discussion Questions

- Why is “as many participants as possible” not always the best strategy?
- How does margin of error change the required sample size?
- When should a researcher use power analysis instead of a proportion formula?
- How can nonresponse affect validity even if the numerical sample size is reached?
- What assumptions should be reported in a methodology section?
- Why might a qualitative study not use a formula-based sample size?
- How can ethical review committees evaluate sample size decisions?

Knowledge Check

- 1. What does margin of error describe?
- 2. In the proportion formula, why is p = 0.50 often used when p is unknown?
- 3. Which sample size approach is used to test a group difference?
- 4. What does finite population correction require?
- 5. Should a calculated sample size be rounded up or down?
- 6. What is the difference between invited sample and completed sample?
- 7. Name one reason a large sample may still produce biased results.
- 8. What should be documented when reporting a sample size calculation?

Knowledge Check: Answer Key

- 1. The acceptable amount of error around a sample estimate.
- 2. It gives the most conservative sample size for a proportion when variability is unknown.
- 3. Power analysis.
- 4. A known population size N and an initial sample size n_0.
- 5. Round up.
- 6. Invited sample is contacted; completed sample provides usable data.
- 7. Poor sampling frame, nonresponse bias, measurement error, or unrepresentative recruitment.
- 8. Formula/method, assumptions, confidence level, margin of error or power, population size, response-rate adjustment, and final target.

Key Takeaways

- Sample size should be planned before data collection.
- The correct method depends on whether the study estimates a value or tests a hypothesis.
- Confidence level, margin of error, variability, effect size, power, and design influence the final number.
- Finite population, nonresponse, and design-effect adjustments may be necessary.
- A justified sample size improves credibility, feasibility, ethics, and reporting quality.

Calculate, adjust, justify, and report.

Conclusion

Sample size calculation is a core part of research planning. It helps researchers decide how much data they need to answer a research question with appropriate precision, power, and credibility.

- A good sample size is not just a number; it is a documented methodological decision.
- Researchers should use formulas, software, expert advice, and transparent assumptions responsibly.
- The final sample size must also fit the sampling strategy, ethics, resources, and expected response rate.

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